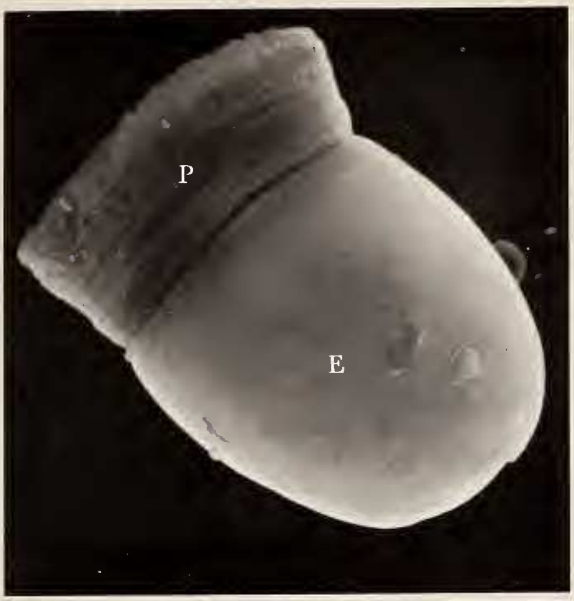

Figure 5

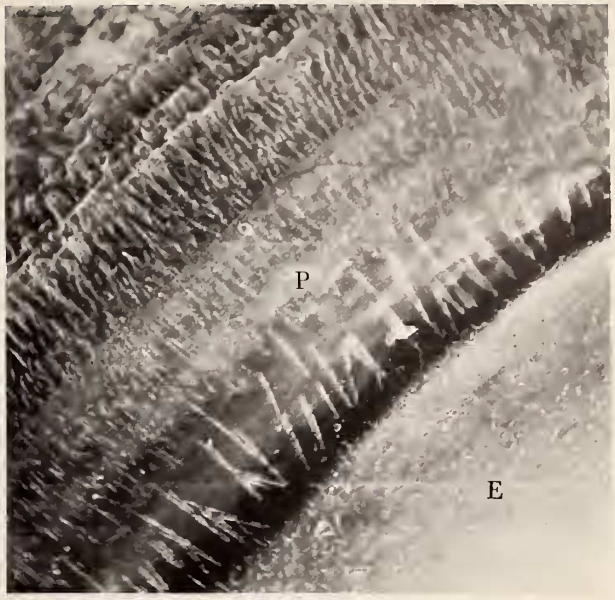

Figure 6

Figure 7

Figure 8

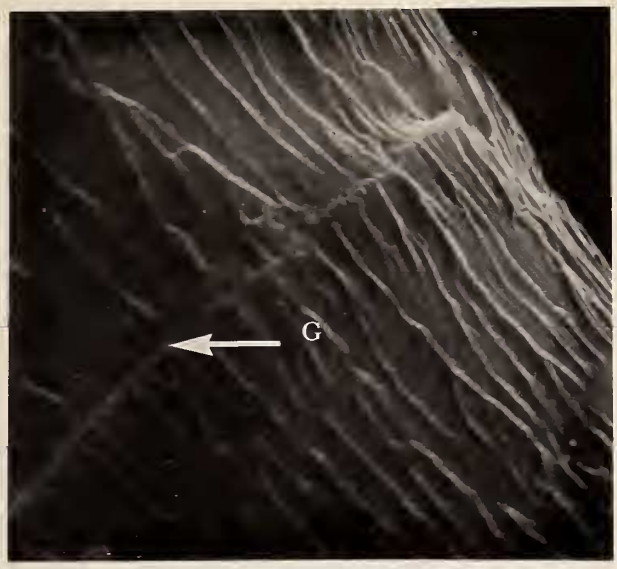

Figure 9

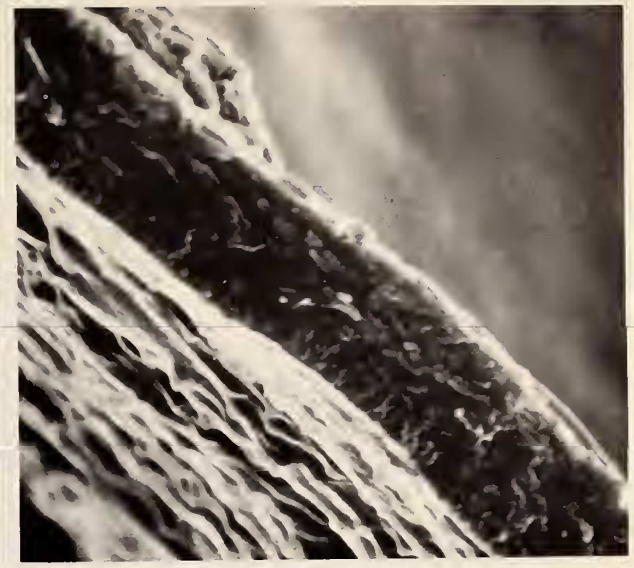

Figure 10

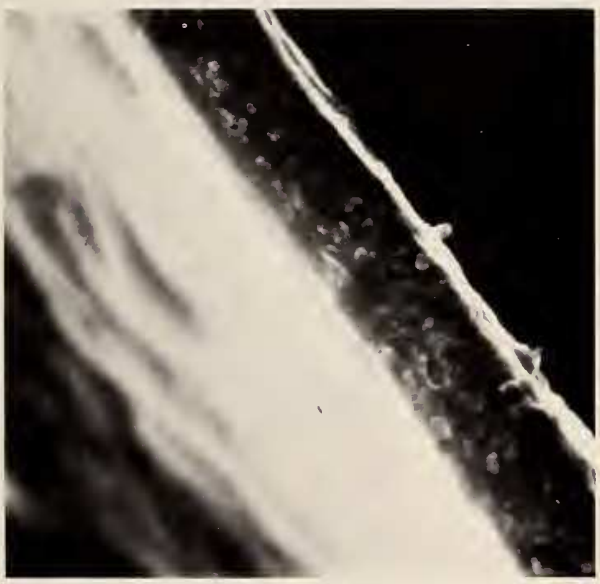

Figure 11

Figure 12

Seasonal Patterns of Abundance and Reproduction of Euthecosomatous Pteropods off Barbados, West Indies [1]

BY

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(7 Text figures)

INTRODUCTION

Euthecosomatous pteropods form one of the few groups of gastropod molluscs adapted to a holoplanktonic existence. However, euthecosomes are poorly known, with only the taxonomy and species distribution having been studied in detail. Quantitative studies of population densities and seasonal abundance have been conducted in only a few tropical or subtropical areas: the North Atlantic (Chen & Bé, 1964), off Cape Hatteras (Myers, 1968; Chen & Hillman, 1970), in the Gulf Stream off Florida (Wormelle, 1962), and in the Mediterranean (Thiriot-Quiévreux, 1968). A study of *Spiratella* ("*Limacina*") *bulimoides* by Morton (1954b) provided the first data on size composition and reproductive capacity of a tropical euthecosome population. This paper reports the results of a two year study of population densities, seasonal variations in abundance, size composition, and reproduction of euthecosomatous pteropods conducted off Barbados from June 1971 to May 1973.

MATERIALS AND METHODS

The sampling program consisted of 3 night plankton tows made twice monthly from June 1971 to May 1973 at a 350 m deep station about 5 km west of the Bellaire Research Institute, St. James, Barbados, West Indies (13°11′ N; 59°41′ W). Oblique hauls were made from 300 m to the surface with a 1 m open plankton net equipped with a flowmeter and No. 20 (76 μm) nylon mesh. A bathythermograph record was made on each cruise. Samples were immediately preserved in 10% formalin buffered to saturation with hexamethylene tetramine.

Either subsamples or entire preserved tows were sorted for euthecosomes. Counts were made of the number of individuals present of each species for the analysis of seasonal patterns of abundance. At least 200 *Spiratella inflata* were measured each month with a Zeiss dissecting microscope equipped with an ocular micrometer. The maximum shell diameter was measured for *S. inflata* and *S. lesueuri*. Total shell length was measured in all other species. Because *S. trochiformis*, *S. bulimoides*, and the *Creseis* species were not as abundant as *S. inflata*, all available individuals of these species were measured.

Living specimens were obtained from supplementary plankton tows which were diluted in buckets of seawater immediately after collection. These diluted collections were examined under a dissecting microscope in the shore laboratory, and living individuals were transferred by pipette to small glass containers of fresh seawater for examination.

To determine whether embryos were being brooded by female *Spiratella inflata* the animals were decalcified in Bouin's fixative and prepared for detailed microscopical examination. Specimens were stained in eosin and 70% alcohol, dehydrated in an alcohol series, cleared in toluene, and mounted in Permount on a microscope slide. To determine the stages of sexual development specimens of all species of *Spiratella* and *Creseis* were embedded in paraffin and sectioned into serial sections 10 μm thick. All sections were stained in either Ehrlich's hematoxylin and eosin or Mallory's triple stain.

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[1] This paper is adapted from portions of a thesis submitted to the Faculty of Graduate Studies and Research of McGill University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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RESULTS

Species Abundances

Nineteen species and subspecies of euthecosomatous pteropods were collected during the sampling period of June 1971 to May 1973 (Table 1). Two genera were numerically dominant in the samples and were selected for study of their reproductive characteristics. *Spiratella*, with 4 species, constituted 70.0% of all euthecosomes collected, with most of the individuals being *S. inflata*. *Spiratella inflata* was by far the most common species, comprising 61.5 per cent of the total euthecosome population. Three species and subspecies of *Creseis* were 27.3% of the total number of individuals, the most abundant of which was *C. virgula conica* with 23.0%. The remaining 12 species, belonging to 6 genera, together totalled only 2.0% of the number of individuals collected. All species, except *Clio pyramidata* and 3 species collected only in supplementary tows, were collected throughout the years.

The total density of euthecosomes (Figure 1) showed no seasonality, though it tended to be lower in summer than in winter except for sharp peaks in August of both years. The average population density of the second year (5073.1 individuals per 1000 m^3) was higher than in the first year (4053.4) because of the increased numbers of *Creseis virgula conica* and *C. v. virgula* encountered.

Three patterns of seasonal abundance were found: species with no seasonality, species with increased summer abundance, and those with winter maxima. Several species (*Cavolinia inflexa*, *Creseis virgula conica*, *C. v. virgula*, *Diacria trispinosa*, *Spiratella inflata* and *S. lesueuri*) exhibited erratic fluctuations in population densities over the 2 years investigated but showed no patterns of seasonality. The abundance of the most numerous species, *Spiratella inflata*, is shown in Figure 2; the average density was 2949.3 individuals per 1000 m^3 of water filtered. The maximum density of 6292.3 was in August 1971 and the minimum of 1066.4 occurred in July 1972. In all 7 maxima occurred without definite patterns. The average abundances of *S. inflata* in the 2 years were similar, 3033.0 in the first year and 2872.6 in the second. The second most abundant species, *Creseis virgula conica* (Figure 3) demonstrated the same pattern: the average population density of 1103.2 individuals/1000m^3 of water was exceeded in 6 months without seasonal patterns, although the largest

Table 1

Average abundance of euthecosomatous pteropods in samples collected off Barbados from June 1971 to May 1973.

Species	Average abundance No./1000m^3	Percent
Cavolinia gibbosa (d'Orbigny, 1836)	0.1	0.0
Cavolinia inflexa (Rang, 1813)	36.0	0.8
Cavolinia longirostris (Blainville, 1821)	9.3	0.2
Cavolinia tridentata (Niebuhr, 1775)	*	—
Cavolinia uncinata (Rang, 1829)	*	—
Clio balantium (Rang, 1834)	*	—
Clio pyramidata (Linnaeus, 1767)	4.3	0.1
Creseis acicula (Rang, 1828)	64.0	1.3
Creseis virgula conica (Rang, 1829)	1103.2	23.0
Creseis virgula virgula (Rang, 1828)	145.6	3.0
Cuvierina columnella (Rang, 1827)	2.3	0.0
Diacria quadridentata (Blainville, 1821)	0.4	0.0
Diacria trispinosa (Blainville, 1821)	11.0	0.2
Hyalocylix striata (Rang, 1828)	7.7	0.2
Spiratella bulimoides (d'Orbigny, 1836)	105.8	2.2
Spiratella inflata (d'Orbigny, 1836)	2949.3	61.5
Spiratella lesueuri (d'Orbigny, 1836)	18.1	0.4
Spiratella trochiformis (d'Orbigny, 1836)	320.7	6.7
Styliola subula (Quoy and Gaimard, 1827)	18.5	0.4
Total	4796.4	100.0

*collected only in supplementary tows

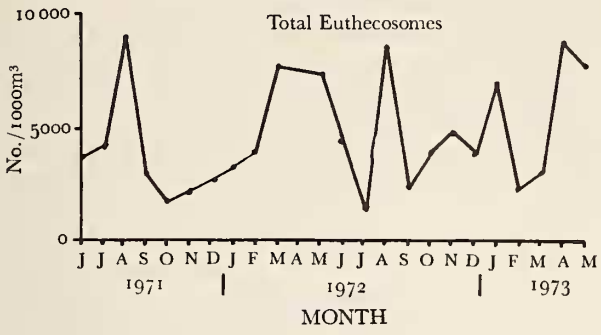

Figure 1

Seasonal abundance of total euthecosome density off Barbados from June 1971 to May 1973

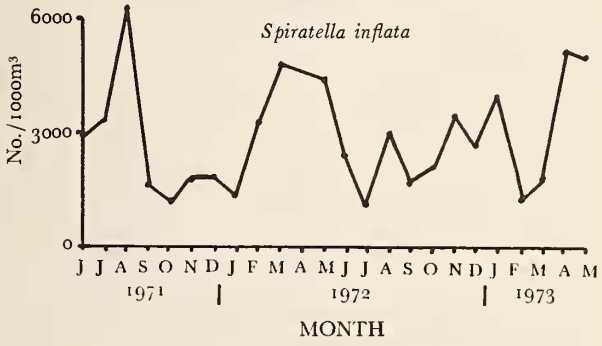

Figure 2

Seasonal abundance of *Spiratella inflata* off Barbados from June 1971 to May 1973

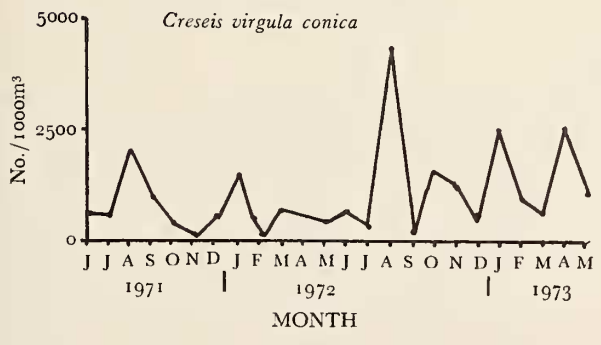

Figure 3

Seasonal abundance of *Creseis virgula conica* off Barbados from June 1971 to May 1973

numbers of individuals were encountered in August of both years. *Creseis virgula conica* had an average density of 753.6 individuals/1000 m³ in the first year and was twice as common, 1423.6, in the second year. A number of other species (*Cavolinia gibbosa*, *C. longirostris*, *C. tridentata*, *C. uncinata*, *Clio balantium*, *Cl. pyramidata*, *Cuvierina columnella*, *Diacria quadridentata*, and *Hyalocylix striata*) were infrequently encountered in the samples and had no obvious seasonal patterns.

Four species (*Creseis acicula*, *Spiratella bulimoides*, *S. trochiformis*, and *Styliola subula*) were present throughout both years but were more numerous in winter than in summer. Both *Spiratella bulimoides* and *S. trochiformis* occurred in small numbers during the summer months (Figure 4). *Spiratella bulimoides* was more common than *S. trochiformis* in the first summer, but the 2 species had about equal densities in the second year. *Spiratella bulimoides* had an increase in numbers in the late winter (March to May) of both years. *Spiratella trochiformis* exhibited the same trends, but the winter increase in population density was much more dramatic. The average density of *S. trochiformis* in the period of June 1971 to February 1972 was 64.0 individuals/1000 m³. During the late winter months of March to June 1972 the density averaged 1396.9, almost a 22 fold increase. The winter increase of the second year was only 6.9 times the summer average, but was still marked enough to show the seasonal change clearly. Although it was encountered in only small numbers, *Styliola subula* also showed a marked winter maximum in both years.

In contrast to the other species with seasonality, *Clio pyramidata* increased in abundance during the summer months. The species was absent, or nearly so, from October

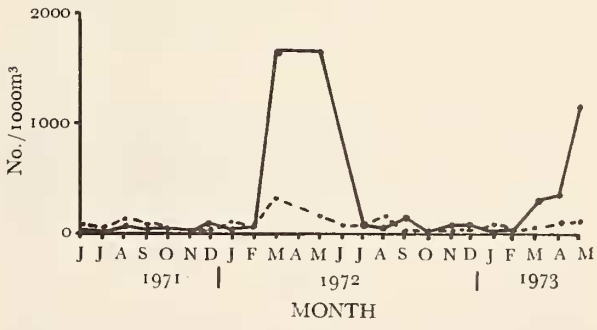

Figure 4

Seasonal abundance of *Spiratella bulimoides* (– – –) and *Spiratella trochiformis* (———) off Barbados from June 1971 to May 1973

to April of both years, and occurred almost exclusively during the summer months.

A Simpson's (1949) index of diversity calculated for the total number of individuals counted each month varied from 0.372 to 0.744. There were no obvious seasonal diversity patterns shown by the index, though the average winter and spring index (0.434) was more diverse than that of the summer and fall (0.521). A t-test conducted on the differences between the winter and summer diversity indices was not significant at the 0.05 level ($t = 0.707$; 22 d. f.). The highest index, 0.744, was recorded in November 1971 during a phytoplankton bloom when the numbers of *Spiratella inflata* in relation to the other species were higher than normal.

Reproductive Cycles

As has been shown above, *Spiratella* and *Creseis* were the dominant genera of the cuthecosome fauna off Barbados. Because of their importance and the availability of specimens, the 2 genera were selected for the study of breeding cycles. All species of *Spiratella* and *Creseis* occurring in Barbados were included except *S. lesueuri*, which was too rare for quantitative analyses.

Females of *Spiratella bulimoides*, *S. lesueuri*, and *S. trochiformis* are thought to deposit floating egg masses in the water column (Lalli & Wells, 1973); a similar reproductive strategy occurs in *Creseis* (Fol, 1875). Embryos are released from the egg masses as free-swimming veligers; sizes of the veligers collected are shown in Table 2. Veligers metamorphose into juveniles which then undergo further development until sexual maturity is reached. Since all species of euthecosomes are protandrous hermaphrodites, each individual matures as a functional male, then continues development into a mature female stage. There is no evidence of a second male stage in *Spiratella* or *Creseis*; the female dies after reproduction is completed. *Spiratella inflata* is also protandrous but no egg masses are deposited; instead females 1.1 mm or more in maximum shell diameter retain developing embryos in the mantle cavity. Thirty brooding females had an average of 44.8 embryos attached to the mantle lining. The embryos begin to develop in the posterior mantle cavity just outside the gonopore and move forward as they develop and grow larger. Veligers with a shell of a single sinistral whorl are released into the plankton at a size of 0.067 mm (Lalli & Wells, 1973). Sizes at which the various life stages occurred in the Barbados populations of *Spiratella* and *Creseis* are shown in Table 2.

The percentage each life stage constituted of the overall population of each species during the 2 years is also shown in Table 2. Since size-frequency histograms of all species showed similar patterns, only histograms of the 2 most abundant species are shown; complete data are included in Wells (1974). Very few individuals of *Spiratella inflata* smaller than 0.1 mm were collected (Figure 5A), with most of this size range being the period in which development takes place in the mantle cavity of the female. The majority (65.3%) of the population consisted of individuals recently released from the parent and in the 0.1 to 0.2 mm size range. The number of individuals in each size range declined sharply with increasing size until a minimum was reached at 0.9 mm. A small subsequent peak occurred after 0.9 mm, the size at which the shell rib developed. Graphs of *S. bulimoides* and *S. trochiformis* were similar. *Creseis virgula conica* (Figure 5B)

Table 2

Sizes and proportions of life stages of *Spiratella* and *Creseis* off Barbados.

Species	Parameter measured	Minimum size collected (mm)	Size at metamorphosis (mm)	Adult size (mm)	Maximum size (mm)	Veligers (%)	Juveniles (%)	Adults (%)
Spiratella bulimoides	Length	0.10	0.3	1.1	1.38	67.2	29.2	3.6
Spiratella inflata	Width	0.07	0.4	1.0	1.35	89.9	7.0	3.2
Spiratella lesueuri	Width	0.20	0.4	1.1	1.45	—	—	—
Spiratella trochiformis	Length	0.10	0.25	0.8	1.02	59.4	38.9	1.8
Creseis acicula	Length	0.30	1.2	6.5	9.60	31.9	66.4	1.7
Creseis virgula conica	Length	0.15	0.6	3.0	4.25	41.5	57.4	0.9
Creseis virgula virgula	Length	0.18	0.6	3.5	5.50	47.6	48.4	0.6